Effects of an Audiovisual Immersive Experience on Mind, Brain, and Body
A Neuroscientific Research Report From Chromasonic

Principal Investigator:
Kingson Man, Ph.D.
kingson@feelingmachines.net

April 2024

Abstract

Chromasonic Immersion is an audiovisual immersive experience designed to foster contemplative states and enhance psychological well-being. This study investigated the experience's impact on participants, encompassing behavioral/psychological and neural/physiological assessments. Compared to a control group, those who underwent the Chromasonic experience exhibited significant improvements in mood and reductions in anxiety, alongside enhanced mindfulness and attentional control. Neurophysiological measures further revealed changes in brain activity associated with auditory processing, dynamic shifts in mental states, and increased parasympathetic nervous system activity indicative of relaxation. These findings highlight the potential of Chromasonic Immersion as a tool to promote mental well-being and enhance cognitive function, with promising applications in therapeutic and wellness contexts.

Executive Summary

Introduction: Chromasonic Immersion is an audiovisual immersive experience that has powerfully impacted many of its participants. We conducted a rigorous scientific investigation and performed statistical analyses on the effects of the experience on mind, brain, and body.

Methods: The research involved two phases:

- Phase 1 (Behavioral and Psychological): Participants were divided into active and control groups. The active group underwent the Chromasonic experience while the control group viewed a nature video. Several questionnaires and cognitive tasks were administered before and after the experience to assess changes in mood, anxiety, fear of death, mindfulness, and attention.
- Phase 2 (Neural and Physiological): Brain activity (EEG) and physiological data (ECG, heart rate, respiration, and galvanic skin response) were recorded during the experience for the active group. EEG data was analyzed to understand changes in brain activity in response to auditory stimuli before, during, and after the experience.

Highlights From Results:

- Improved Mood and Reduced Anxiety: The active group reported significant improvements in mood, reduced anxiety, and decreased fear of death after the experience.
- Enhanced Mindfulness: Participants in the active group showed increased scores on the decentering subscale of the Toronto Mindfulness Scale, suggesting a greater ability to observe thoughts and feelings without judgment.
- Improved Attentional Control: Only the active group demonstrated significant improvement on the Stroop task, indicating enhanced attentional control after the experience.
- Changes in Time Perception: Both groups perceived brief durations as shorter after the experience, suggesting an altered sense of time that may be related to occupying the installation space, a common factor between the control and active groups.
- Neural Changes: EEG results revealed complex changes in brain activity after the experience, particularly in response to unexpected auditory stimuli. This suggests potential effects on sensory processing and attention allocation.
- EEG Time Course Analysis: Examination of EEG power across different frequency bands during the experience revealed dynamic changes potentially reflecting shifts in mental states and engagement throughout the session.
- Physiological Changes: Analysis of heart rate variability indicated increased parasympathetic activity ("rest and digest") during the experience, suggesting a relaxation response.

Conclusion: The audiovisual immersive experience robustly impacted participants' psychological state, cognitive function, and brain activity. The findings suggest that such experiences may have therapeutic potential for improving mood, reducing anxiety, enhancing mindfulness, and promoting relaxation.

Introduction

Immersive experiences, encompassing modalities like virtual reality, soundscapes, and multisensory installations, have garnered increasing interest for their potential to impact cognitive function and emotional well-being (Agrawal & Bech, 2022). These experiences offer unique environments that engage participants on multiple sensory levels, creating opportunities to modulate mood, reduce stress, and enhance cognitive processes. Among these, audiovisual stimulation has demonstrated efficacy in influencing brainwave activity and eliciting specific emotional responses (De Filippi et al., 2021; Hofmann et al., 2021).

The potential of immersive experiences for therapeutic applications is particularly noteworthy. Studies have explored the use of interactive audiovisual virtual reality environments for anxiety reduction, showing promising results in inducing relaxation and improving mental resources (Jyskä et al., 2022). Similarly, research suggests that virtual art exhibits can positively impact mood, even during challenging times like the COVID-19 pandemic (Hadavi et al., 2022). Additionally, virtual reality applications that allow users to create their own environments have been found to foster emotional engagement and well-being (Wagener et al., 2022).

Chromasonic Immersion is a novel audiovisual immersive experience designed to create a transformative environment promoting relaxation, introspection, and connection. Initial observations and anecdotal reports suggested profound impacts on participants' emotional and cognitive states. These reports motivated the creators of Chromasonic Immersion to collect preliminary survey data, which further supported the positive effects of the experience. To gain a deeper understanding of these effects and their underlying mechanisms, this study aimed to rigorously evaluate the impact of the Chromasonic experience on psychological well-being and cognitive function. Additionally, this study sought to explore the neural and physiological correlates of these effects using electroencephalography (EEG) and other physiological measures. By elucidating the effects of Chromasonic Immersion on the mind, brain, and body, this study contributes to the growing body of knowledge on immersive experiences and their potential applications in therapeutic and wellness contexts.

Methods

Participants and Study Design

Participants were recruited from the general population and provided informed consent before participating in this two-phase study. Phase 1 focused on behavioral and psychological assessments, while Phase 2 examined neural and physiological measures. In Phase 1, participants were assigned to either the active group, which underwent the Chromasonic experience, or the control group, which watched a nature documentary. A total of 85 participants were recruited across the phases, with mean age of 35 and approximately 1:3 male to female ratio.

Phase 1: Behavioral and Psychological Assessments

Both groups completed a series of questionnaires before and after their respective experiences, including the Inclusion of Other in Self Scale (Aron et al 1992), the Fear of Death Scale (Lester 1990), the short form of the Profile of Mood States (POMS; Curran et al 1995), the Mystical Experience Questionnaire (MEQ30; Barrett et al 2015) (post-experience only), and the Toronto Mindfulness Scale (TMS; Lau et al 2006) (post-experience only).

Additionally, participants completed two cognitive tasks immediately preceding and following the experience: the Stroop Task (Stroop 1935) and the Temporal Bisection Task (Cowles and Finan 1941). The Stroop Task measures selective attention and the ability to suppress irrelevant information. Participants were presented with the names of colors printed on the screen in a color that either matched or did not match the name (e.g., the word "RED" printed in red or blue ink). The task was to identify the ink color as quickly and accurately as possible, while ignoring the written word. An interference score was calculated as the difference in performance between the congruent and incongruent conditions. Each condition's performance was defined as total reaction time plus the product of the mean reaction time and the number of errors (Gardner et al 1959, reviewed by Scarpina and Tagini 2017).

The Temporal Bisection Task assessed the perception of time duration. Subjects were presented with beeps of varying durations between 0.4 and 1.6 seconds and asked to judge whether each beep was longer or shorter than a reference 1-second beep. A point of temporal indifference was estimated by fitting a Weibull function to the collected data, which was then used to construct the psychometric function. This method determines the threshold at which participants are equally likely to choose between two temporal intervals, providing insights into their perception of time under varying conditions.

Stimuli for these tasks were presented with precise timing using custom scripts in PsychoPy (Peirce 2007). For each questionnaire and cognitive task, one-sample t-tests were conducted to compare the difference in group means before and after the experience for both the active and control groups.

Phase 2: Neural and Physiological Measures

In Phase 2, participants only in an active group underwent EEG and physiological recordings before, during, and after the Chromasonic experience. EEG data were collected using the Emotiv EPOC-X EEG headset, which features 14 EEG channels and 2 reference channels, sampling at 128 Hz with a 0.2-45 Hz bandpass filter. Recordings were time-locked to PsychoPy for precise synchronization with the stimulus events. EEG data were processed in MNE-Python (Gramfort et al 2013) by re-referencing to the global mean, de-trending, and epoching. Artifact rejection/replacement was performed with a machine learning algorithm using the Autoreject package in Python (Jas et al 2017).

For the auditory oddball task, participants listened to presentations of a standard tone of 440Hz and an oddball tone of 660Hz, each of 250 ms duration, in a 5:1 ratio. Stimuli were randomly ordered in four runs of 60 presentations each. The task was performed before and after the experience. EEG data were time-locked to each stimulus presentation and averaged to generate event-related potentials (ERPs). EEG signals underwent baseline correction, artifact rejection, and averaging. For EEG time course analysis during the experience, global field power was calculated for four frequency bands: theta (4-8 Hz), alpha (8-12 Hz), beta (12-30 Hz), and gamma (30 Hz and greater).

Physiological measures were collected with an Equivital SEM for electrocardiogram (ECG), respiration, and galvanic skin response. Heart rate variability (HRV) was calculated from the ECG by calculating the inter-beat interval and then removing outliers exceeding three times the interquartile range. The root mean square of successive differences (RMSSD) between heartbeats was calculated in a rolling window of 300 seconds (see Laborde et al 2017). RMSSD values were then z-scored for each participant, averaged across subjects, and plotted over time. Respiration rate and galvanic skin response (GSR) data were down-sampled to 1 Hz and smoothed using a 30-second rolling window. The data were then z-scored within each participant's timecourse and averaged across subjects, plotted over time with SEM.

Results

Phase 1: Behavioral and Psychological Findings

Inclusion of Other in Self and Fear of Death

There were no significant changes in the Inclusion of Other in Self scores following the experience for either group. However, the active group exhibited a significant reduction in Fear of Death scores compared to the control group (Fig. 1).

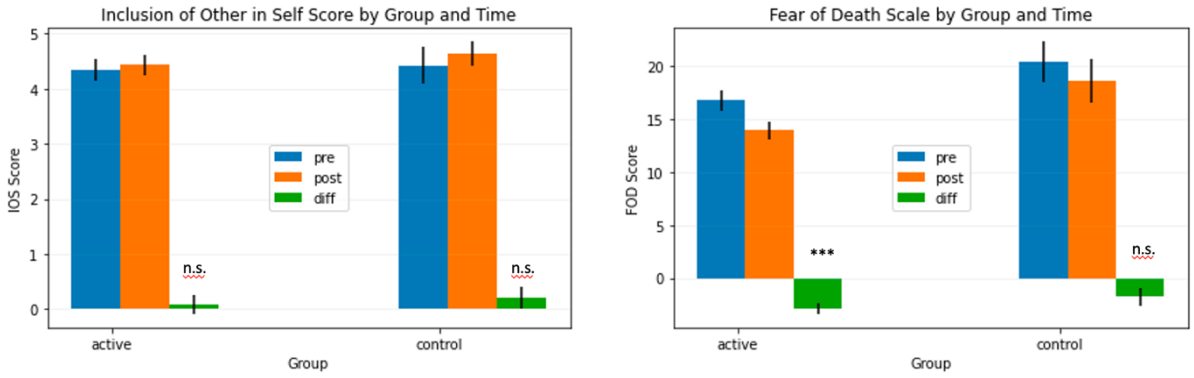

Figure 1. Inclusion of Other in Self and Fear of Death Scale Scores. Bars display the mean score for each group, before and after the experience. Vertical lines at the tops of bars represent standard error of the mean. Asterisks throughout indicate significant differences (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s., not significant).

Profile of Mood States

The active group reported significant improvements in mood across five out of six subscales of the POMS questionnaire after the experience. These included reductions in anxiety, depression, anger, fatigue, and confusion (Fig. 2). For the control group, only the anxiety subscale was significantly different post-experience. Individual-level data further illustrated the variety of mood improvements in the active group (Fig. 3).

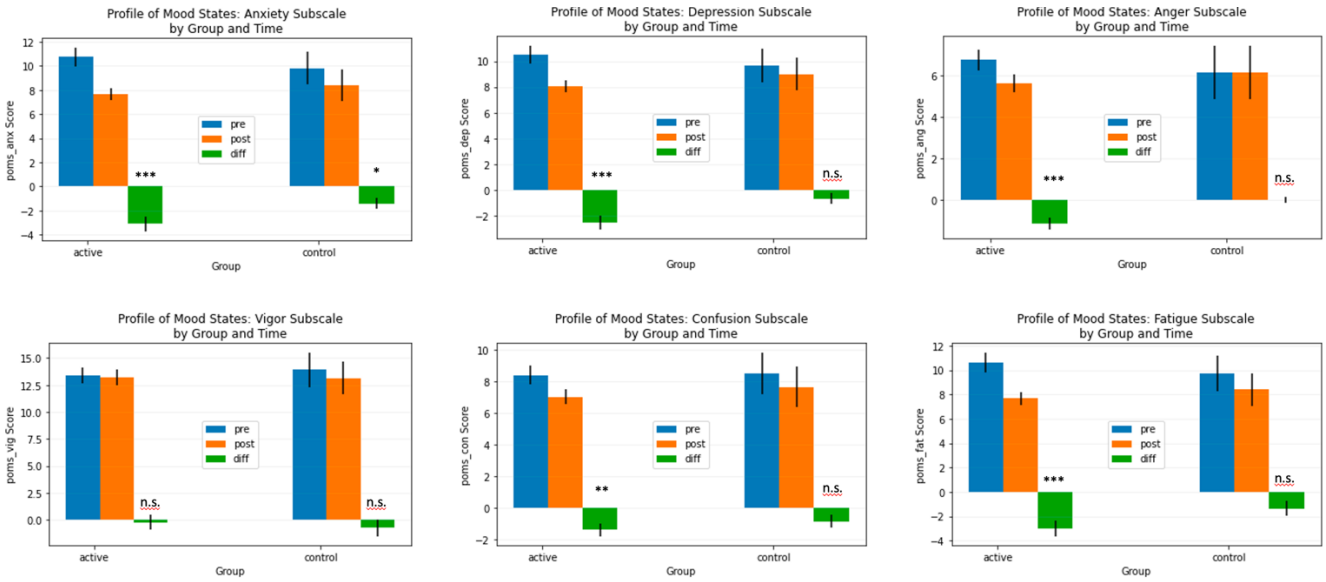

Figure 2. Profile of Mood States Subscale Scores.

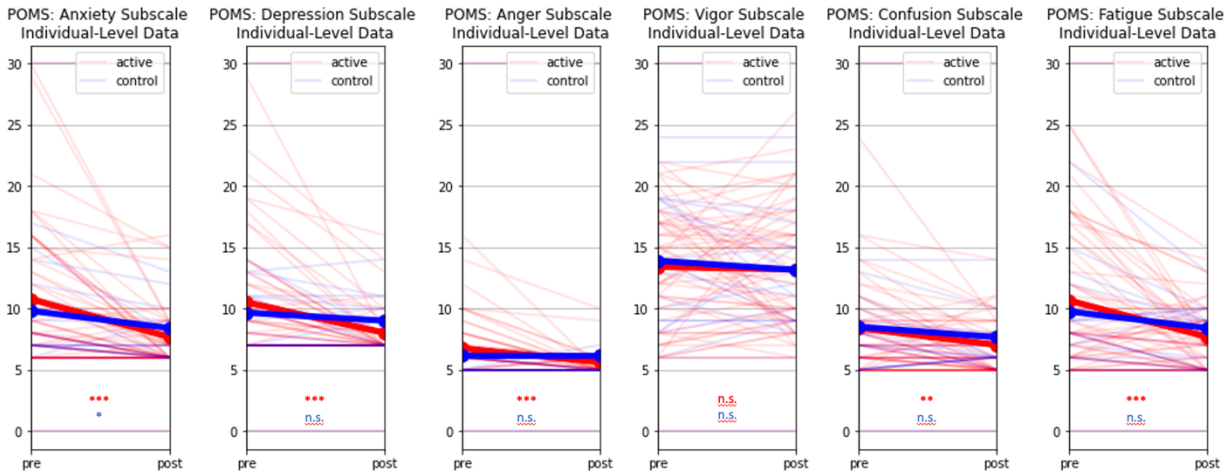

Figure 3. Individual-Level POMS Data. Thin lines represent individual participants, connecting their measurements pre- and post-experience. Thick lines indicate the means for each group, with active condition in red and control condition in blue. Results of significance testing for difference of means pre- and post-experience are color coded by group.

Mystical Experience Questionnaire and Toronto Mindfulness Scale

Post-experience assessments revealed that the active group scored significantly higher on all four factors of the MEQ30, indicating a greater sense of mystical experience compared to the control group (Fig. 4, left). Participants who scored at or above 60% on all four subscales of the MEQ30 were classified as having had a "complete mystical experience" (Barrett et al 2015). This was the case for nearly half of the active group participants (47%; 27 out of 58), but only 17% of the control group participants (3 out of 18). Additionally, the active group showed significantly higher scores on the decentering subscale of the TMS, suggesting an increased ability to observe thoughts and feelings without judgment (Fig. 4, right).

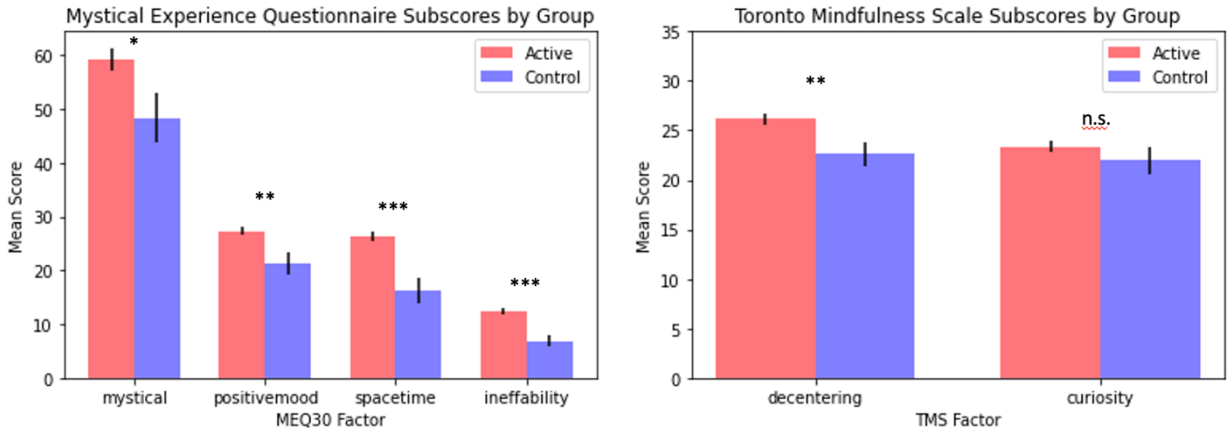

Figure 4. Post-Experience Questionnaires. Mystical Experience Questionnaire and Toronto Mindfulness Scale Scores, reported at the factor level.

Stroop Task and Temporal Bisection Task

Only the active group demonstrated significant improvement on the Stroop task, indicating enhanced attentional control following the Chromasonic experience (Fig. 5, left). In the Temporal Bisection Task, both groups perceived brief durations as shorter after the experience, suggesting an altered sense of time simply by occupying the installation space (Fig. 5, right).

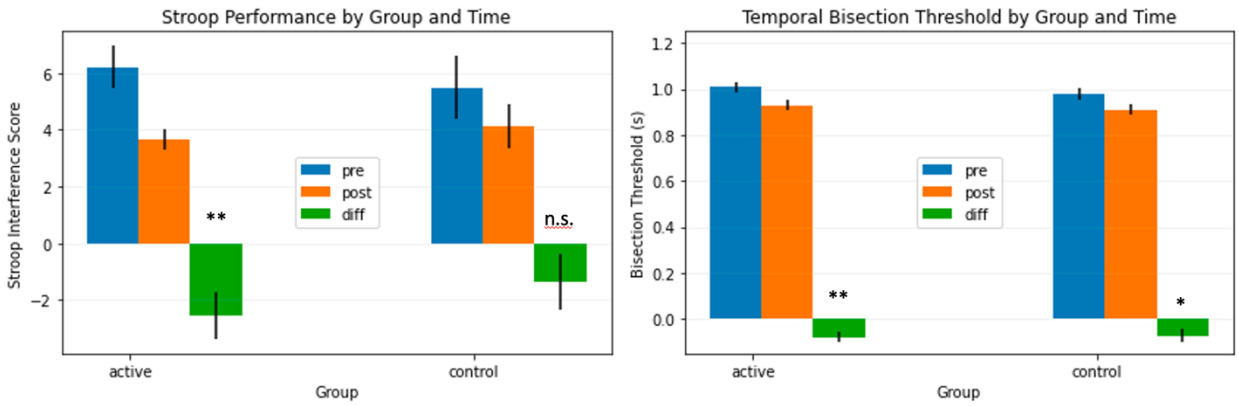

Figure 5. Performance on cognitive tasks before and after the experience.

Phase 2: Neural and Physiological Findings

Analysis of EEG and physiological data provided further insights into the effects of the Chromasonic experience on brain activity and bodily responses.

Auditory Processing

ERP data from the auditory task revealed changes in brain activity associated with the processing of unexpected "oddball" auditory stimuli (Fig. 6). Specifically, the auditory novelty effect, characterized by a difference in neural responses to unexpected rare tones versus standard tones, was significantly reduced after the Chromasonic experience. This suggests that the experience may have influenced sensory processing and attentional mechanisms, leading to a decreased sensitivity or reactivity to unexpected sounds.

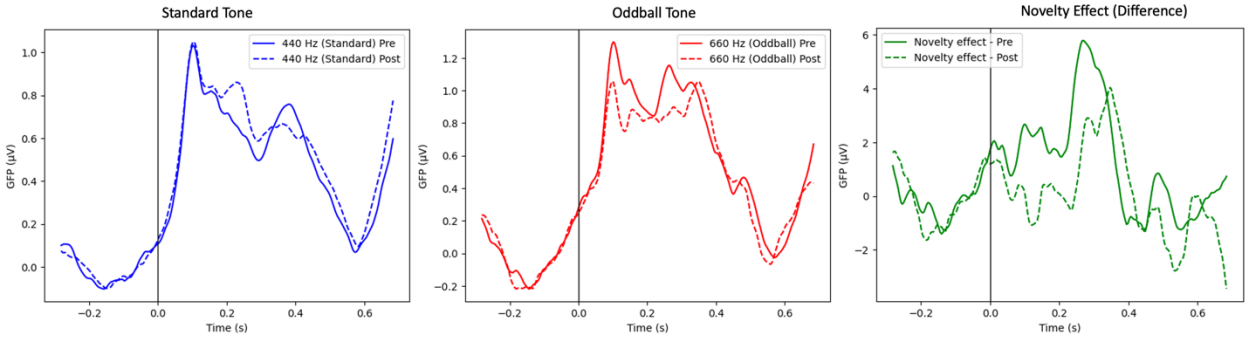

Figure 6. Auditory Novelty Effect ERP Study. *Left*, ERP response to the standard tone showed a minor, mixed effect before (solid line) and after (dotted line) the experience. *Middle*, Evoked responses to the oddball tone showed a slight decline after the experience around the 100ms and 300ms latencies. *Right*, the novelty effect, or difference in brain response between the standard and oddball tones, showed marked decline after the experience between the 100ms and 300ms latencies, and also in a late component around 500ms.

Dynamic Changes in Brain Activity

Examination of global EEG power across different frequency bands during the Chromasonic experience revealed dynamic shifts reflecting evolving mental states and levels of engagement throughout the session (Fig. 7).

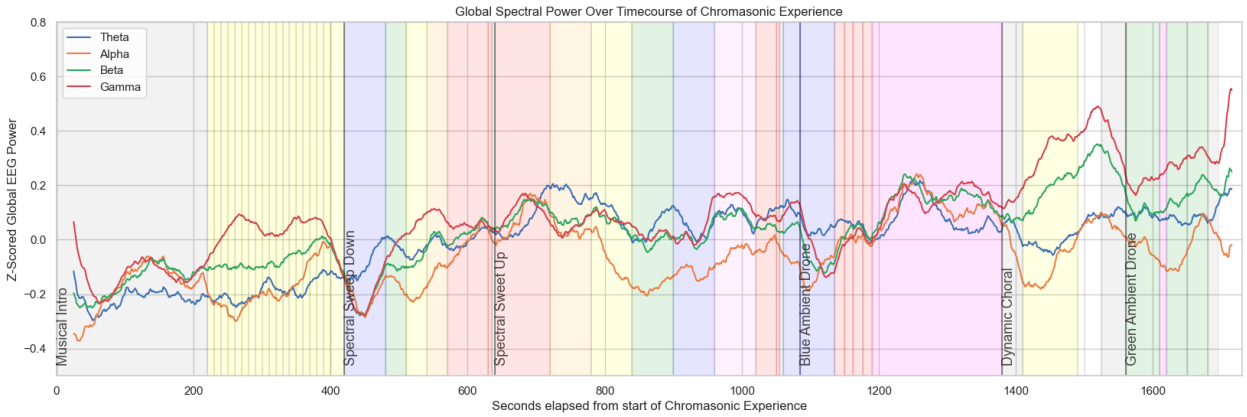

Figure 7. EEG Band Power Across the Time Course of the Chromasonic Experience. EEG data are presented on a background visualizing the dominant color and audiovisual pulse events of the experience. Frequency-specific power, decomposed into four different bands, reveals dynamic changes corresponding to different portions of the experience. In particular, gamma activity was selectively elevated during the musical intro pulses between 200-400 s; alpha activity was selectively suppressed between 800 and 1000 s; and there was a complex pattern of suppressed alpha and elevated gamma and beta activity between 1400 and 1550 s.

Heart Rate Variability

Analysis of heart rate variability (HRV), an index of vagal tone, indicated a slow rise and fall during the middle third of the Chromasonic experience, peaking around 1000 s (Fig. 8). Vagus and parasympathetic nervous system activity is associated with the "rest and digest" response, suggesting that the experience elicited a state of relaxation in participants. This finding is consistent with the self-reported reductions in anxiety and improvements in mood observed in Phase 1.

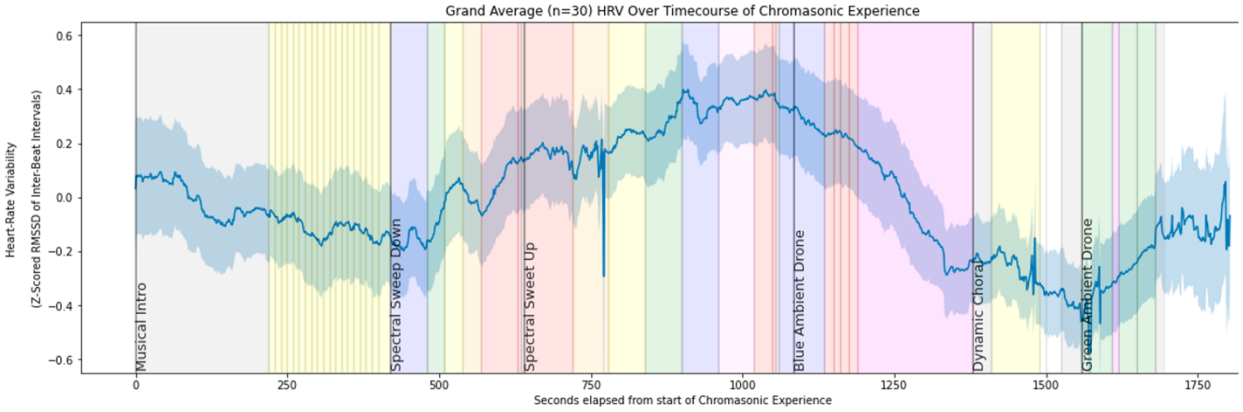

Figure 8. Changes in heart rate variability during the Chromasonic experience. HRV showed a slow rise, peak, and return to baseline, during the middle third of the experience.

Fluctuations in Physiological Arousal and Engagement

Changes in heart rate, respiration rate, and GSR throughout the Chromasonic experience demonstrated fluctuations that likely correspond to shifts in arousal and emotional engagement (Fig. 9). These physiological responses provide further evidence of the dynamic and multifaceted impact of the experience on the body.

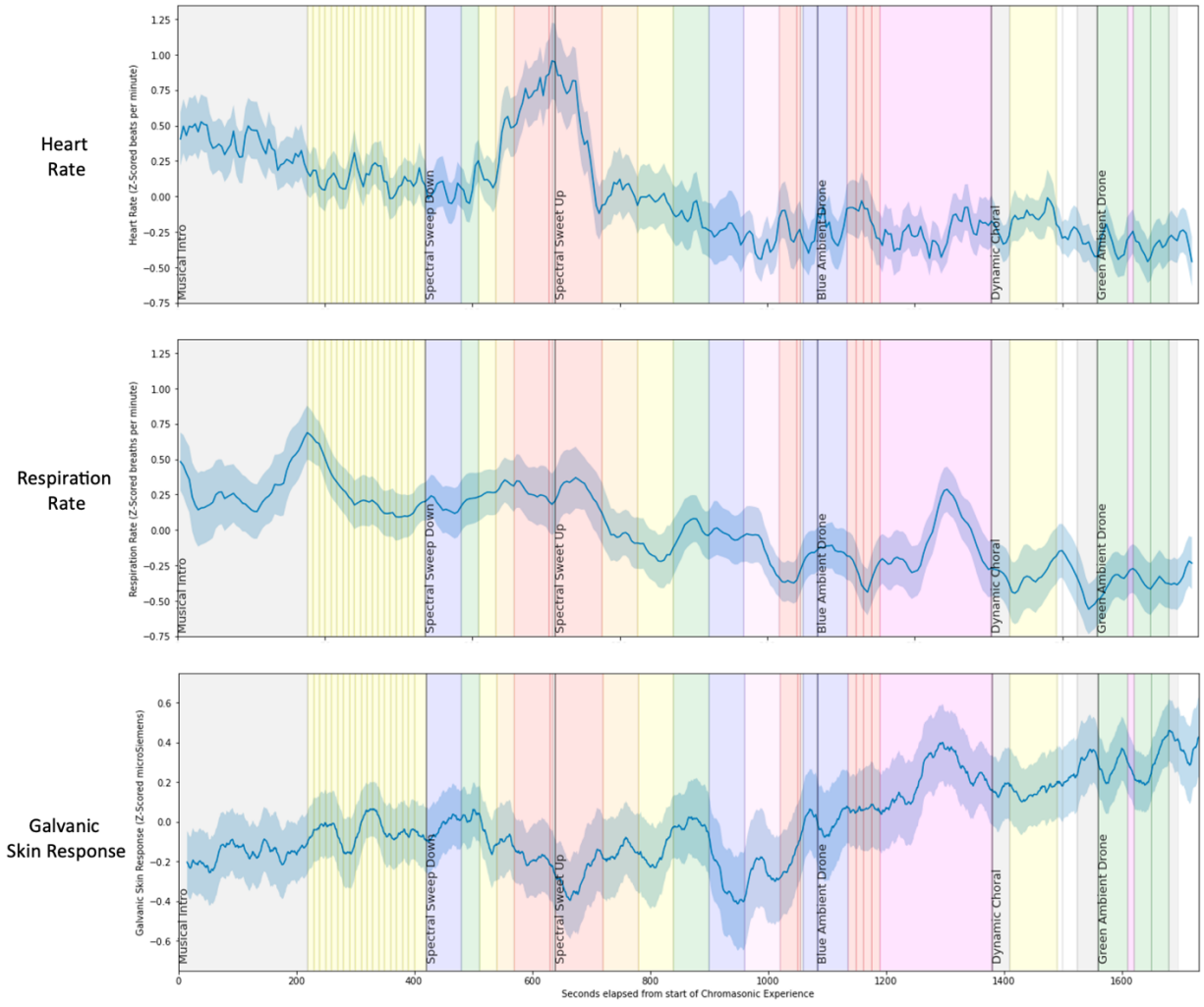

Figure 9. Physiological changes over the time course of the Chromasonic experience. Heart rate showed significant rise before return to baseline during the Spectral Sweep Up around 600 s. Respiration rate showed two distinct peaks around the transition point of the musical intro, at 200 s, and during the latter portion of the Blue Ambient

Drone phase at 1250 s. Galvanic skin response peaked in synchrony with respiration rate peak during the Blue Ambient Drone.

Discussion

The findings of this study provide compelling evidence for the multifaceted impact of the Chromasonic Immersion experience on psychological well-being, cognitive function, and physiological responses. Participants who underwent the experience reported strongly significant improvements in mood, reductions in anxiety and fear of death, and enhancements in mindfulness and attentional control. These benefits were nearly entirely absent in the control group. Neurophysiological measures corroborated these findings, revealing changes in brain activity associated with auditory processing, dynamic shifts in mental states, and increased parasympathetic activity indicative of relaxation.

These results align with a growing body of research demonstrating the positive effects of immersive audiovisual experiences on well-being and cognition. Similar to studies on virtual reality environments designed for anxiety reduction (Jyskä et al 2022), Chromasonic Immersion elicited significant decreases in anxiety and improvements in mood, suggesting a shared mechanism for promoting relaxation and emotional well-being across different immersive formats.

The 47% incidence of a complete mystical experience observed within the active group is remarkable for a non-pharmacological intervention. A study of participants in a month-long meditation retreat found a 20% incidence of complete mystical experience (Zanesco et al 2023); these may be compared to studies of high-dose psilocybin administration that found 58-67% incidence of complete mystical experience (Griffiths et al 2008).

The observed improvements in attentional control echo research on the potential of immersive environments to enhance cognitive function, including virtual reality simulations for assessing and training attentional processes (Kamińska et al 2021). Chromasonic's impact on sensory processing and attentional mechanisms, evidenced by the reduction in the auditory novelty effect and dynamic changes in EEG band power, aligns with participants' reports of deep immersion and focus. This suggests that Chromasonic may offer a complementary approach to traditional cognitive training methods.

Furthermore, the dynamic changes in EEG band power observed during the Chromasonic experience provide valuable insights into the neural mechanisms underlying its effects. These findings align with research exploring the use of EEG to classify and decode emotional states during immersive virtual reality experiences (De Filippi et al 2021; Hofmann et al 2021). Future research could leverage this information to optimize the design of immersive experiences for specific therapeutic goals, such as mood regulation or stress reduction.

Limitations and Future Directions

While this study offers some insights into the effects of Chromasonic Immersion, several limitations should be considered. The sample size, particularly for the control group, was relatively small, and future studies with larger and more age- and sex-diverse samples would be warranted to enhance the generalizability of the findings. Additionally, participants were pre-screened for good physical and mental health, leaving the potential benefits for individuals with neurological or mood disorders unexplored. Finally, the inclusion of an active control group engaging in a different relaxation or mindfulness practice would provide a more direct comparison and help isolate the specific effects of Chromasonic. Exploring the long-term effects and potential applications in various therapeutic and wellness settings is also crucial.

The use of EEG and physiological recordings holds significant potential for optimizing future experience designs. By analyzing the dynamic changes in brain activity and bodily responses during immersive experiences, researchers and designers can identify the specific elements that contribute to emotional engagement or relaxation. This information can then be used to refine and tailor experiences to maximize their desired effects. For example, EEG data could be used to identify the auditory or visual features that elicit the strongest relaxation response, while physiological measures could provide insights into the optimal pacing and intensity of stimulation.

Conclusion

The findings of this study support the potential of Chromasonic Immersion as a unique and effective tool for enhancing psychological well-being, cognitive function, and physiological state. The observed improvements in mood, reductions in anxiety, enhancements in mindfulness, and promotion of relaxation suggest promising applications for this immersive experience in various contexts, including mental health, stress management, and overall wellness promotion.

References

Agrawal SR, Bech S. Immersion in audiovisual experiences. InSonic Interactions in Virtual Environments 2022 Oct 14 (pp. 319-351). Cham: Springer International Publishing.

Aron A, Aron EN, Smollan D. Inclusion of other in the self scale and the structure of interpersonal closeness. Journal of personality and social psychology. 1992 Oct;63(4):596.

Barrett FS, Johnson MW, Griffiths RR. Validation of the revised Mystical Experience Questionnaire in experimental sessions with psilocybin. Journal of psychopharmacology. 2015 Nov;29(11):1182-90.

Cowles JT, Finan JL. An improved method for establishing temporal discrimination in white rats. The Journal of Psychology. 1941 Apr 1;11(2):335-42.

Curran SL, Andrykowski MA, Studts JL. Short form of the profile of mood states (POMS-SF): psychometric information. Psychological assessment. 1995 Mar;7(1):80.

David Lester (1990) The collett-lester fear of death scale: The original version and a revision, Death Studies, 14:5, 451-468, DOI: 10.1080/07481189008252385

De Filippi E, Wolter M, Melo BR, Tierra-Criollo CJ, Bortolini T, Deco G, Moll J. Classification of complex emotions using EEG and virtual environment: Proof of concept and therapeutic implication. Frontiers in Human Neuroscience. 2021 Aug 26;15:711279.

Gardner, R. W., Holzman, P. S., Klein, G. S., Linton, H. P., and Spence, D. P. (1959). Cognitive control: a study of individual consistencies in cognitive behaviour. Psychol. Issues 1, 1–186.

Gramfort A, Luessi M, Larson E, Engemann DA, Strohmeier D, Brodbeck C, Goj R, Jas M, Brooks T, Parkkonen L, Hämäläinen M. MEG and EEG data analysis with MNE-Python. Frontiers in neuroscience. 2013 Dec 26;7:70133.

Griffiths RR, Richards WA, Johnson MW, McCann UD, Jesse R. Mystical-type experiences occasioned by psilocybin mediate the attribution of personal meaning and spiritual significance 14 months later. Journal of psychopharmacology. 2008 Aug;22(6):621-32.

Hadavi S, Kennedy KG, Mariotti G, DeSouza JF. VisualEars: How an immersive art exhibit impacts mood during the COVID-19 pandemic. Frontiers in Psychology. 2022 Oct 6;13:910767.

Hofmann SM, Klotzsche F, Mariola A, Nikulin V, Villringer A, Gaebler M. Decoding subjective emotional arousal from EEG during an immersive virtual reality experience. Elife. 2021 Oct 28;10:e64812.

Jas M, Engemann DA, Bekhti Y, Raimondo F, Gramfort A. Autoreject: Automated artifact rejection for MEG and EEG data. NeuroImage. 2017 Oct 1;159:417-29.

Jyskä I, Puura K, Turunen M. Therapeutic Potential of Interactive Audiovisual 360-Degree Virtual Reality Environments for Anxiety Reduction—A Case Study with an Abstract Art Application. Applied Sciences. 2022 Sep 16;12(18):9316.

Kamińska D, Smółka K, Zwoliński G. Detection of mental stress through EEG signal in virtual reality environment. Electronics. 2021 Nov 18;10(22):2840.

Laborde S, Mosley E, Thayer JF. Heart rate variability and cardiac vagal tone in psychophysiological research–recommendations for experiment planning, data analysis, and data reporting. Frontiers in psychology. 2017 Feb 20;8:238557.

Lau MA, Bishop SR, Segal ZV, Buis T, Anderson ND, Carlson L, Shapiro S, Carmody J, Abbey S, Devins G. The Toronto mindfulness scale: Development and validation. Journal of clinical psychology. 2006 Dec;62(12):1445-67.

Peirce JW. PsychoPy—psychophysics software in Python. Journal of neuroscience methods. 2007 May 15;162(1-2):8-13.

Scarpina F, Tagini S. The stroop color and word test. Frontiers in psychology. 2017 Apr 12;8:241674.

Stroop JR. Studies of interference in serial verbal reactions. Journal of experimental psychology. 1935 Dec;18(6):643.

Wagener N, Niess J, Rogers Y, Schöning J. Mood worlds: A virtual environment for autonomous emotional expression. In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems 2022 Apr 27 (pp. 1-16).

Zanesco AP, King BG, Conklin QA, Saron CD. The Occurrence of Psychologically Profound, Meaningful, and Mystical Experiences During a Month-Long Meditation Retreat. Mindfulness. 2023 Mar;14(3):606-21.